UNIVERSITI PUTRA MALAYSIA

BIOLOGICAL UTILIZATION OF FIBRE IN SWINE UNDER VARIOUS NUTRIENT REGIMES

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A thesis presented to the Senate of

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Degree of Master of Science

BIOLOGICAL UTILIZATION OF FIBRE
IN SWINE UNDER VARIOUS
NUTRIENT REGIMES

By

Ong Hwee Keng

February 1984

Supervisor: Professor Rudy I. Hutagalung, DVM, Ph.D.

Faculty : Veterinary Medicine and

Animal Sciences

DEDICATION

To my supervisor and all readers:

Do you know the time the mountain goats give birth?

Do you observe the calving of the dear?

Who sent out the wild donkey free?

And who loosed the bonds of the swift donkey?

Will the wild ox consent to serve you?

Or will he spend the night at your manger?

Do you clothe his neck with mane

Is it by your understanding that the hawk soars?

Stretching his wings toward the south?

Is it at your command that the eagle mounts up?

And makes his nest on high?

Job 39: 1, 5, 9, 19, 26, 27

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LIST OF ABBREVIATIONS

ADG	Average daily gain
ADI	Average daily intake
ADF	Acid detergent fibre
ADL	Acid detergent lignin
BDG	Brewers dried grains
CAD	Coefficient of apparent digestibility
CF	Crude fibre
CLM	'China leaf meal'
CP	Crude protein
DE	Digestible energy
DM	Dry matter
EE	Ether extract
GE	Gross energy
Kcal	Kilocalories
ME	Metabolisable energy
MFN	Metabolic faecal nitrogen
MJ	Megajoules
N	Nitrogen
NDF	Neutral detergent fibre
NFE	Nitrogen-free extract
NPE	Non-protein energy
VFA	Volatile fatty acids

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ABSTRACT

Five experiments were conducted to study the biological utilization of fibre in growing-finishing pigs under various nutrient regimes. Two fibrous feedstuffs viz 'China leaf meal' (CLM) and 'brewers dried grains (BDG) were used as the main fibre sources.

In Experiment 1, the chemical composition, fibre and bulk characteristics of CLM and BDG were elucidated. Samples were analyzed for dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), total ash, neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), cellulose, hemicellulose, calcium, phosphorus and amino acids. Characterization of the wet and dry bulk of CLM and BDG in terms of weight per unit volume, increased wet volume on soaking and relative dry volume showed that BDG had a higher bulk than did CLM. If ground maize were indexed at 100% for weight per unit volume, CLM and BDG showed an equivalent relative weight of 44.8 and 27.8%, respectively.

Experiment 2 was conducted to study the effects of levels of CLM and BDG on the coefficients of apparent digestibilities (CAD) of nutrients. CAD of CP, EE, NDF and gross energy (GE) decreased linearly with increased level of dietary CLM. Likewise, increased dietary level of BDG linearly decreased CAD of CP, ash, NDF and GE but not EE. The mean digestible energy (DE) on a dry matter basis were 9.29 and 9.77 MJ/kg, respectively for CLM and BDG.

Experiment 3 consisted of two feeding trials on the effects of graded levels of CLM or BDG in isocaloric (approximately 14 MJ/kg) and isonitrogenous (16-14% CP during growing and finishing periods) diets on performance and carcass characteristics of growing-finishing

pigs. Average daily gain (ADG) and feed conversion efficiency were poorer when dietary CLM level exceeded 15%. Carcass characteristics were not significantly affected by CLM levels. Growth performance was adversely affected when dietary BDG level exceeded 10%. Pigs consuming diets with more than 10%. Pigs consuming diets with more than 10% BDG had significantly thinner backfat.

Experiment 4 was carried out to study the effects of levels of energy and fibre (contributed largely by CLM and BDG) on performance and carcass characteristics of growing-finishing pigs. ADG and dressing percentage decreased with increased dietary fibre. Similarly, with increased dietary fibre, percent digestive tracts was increased while backfat thickness decreased. Dietary fibre did not significantly affect _l. dorsi_ areas, lean cuts, primal cuts and bone ash content. Pigs fed diets with less than 13 MJ/kg DE performed poorly compared with those fed energy level exceeding 13 MJ/kg. Dressing percentage, backfat thickness and total fats increased with increase in dietary energy. However, dietary energy did not significantly affect _l. dorsi_ area, lean cuts, primal cuts and bone ash content. There were no significant interactive effects between fibre and energy.

Experiment 5 was aimed at studying the effects of levels of dietary fibre on the performance and carcass characteristics of pigs receiving diets with varying levels of CP. Pigs fed low protein diet (14-12% during growing-finishing period) had significantly reduced ADG compared with those consuming higher CP. However, there was no advantage in feeding pigs with more than 17-15% dietary CP. There were no significant differences in carcass traits between CP levels except that pigs fed low CP had thicker backfat. The interactive effects of fibre and protein were not significant.

CHAPTER I

INTRODUCTION

The continuing increase in world population creates increasing demand for protein, leading to the need for increased animal production and consequently increased feed production. Unfortunately, feed prices continued to increase over the years. With the onset of economic difficulty, it is imperative that there should be increased emphasis on livestock production using materials which are non-competitive in terms of food resources utilization between humans and animals. This is especially true for pig production in which no less than 70% of the total cost of production goes to the feed. This points to the fact that there should be increased utilization of agro-industrial wastes and other secondary raw materials as feeds. However, in Malaysia, these types of feedstuffs or potential feedstuffs such as palm oil mill effluent, rubber seed meal, cocoa pod husk, leaf meals and brewers dried grains, tend to be fibrous.

Fibre constitutes a major portion of ruminant diets due to the complex nature of their digestive system. Since it was believed to be of little nutritional value, fibre was usually added in low concentrations in the diets of non-ruminants. More recent evidence suggest, however, that fibre should not be treated as a non-nutritive substance and that the pig can tolerate more fibre than it was once thought (Farrell, 1973; Keys and Debarthe, 1974; Kass *et al.*, 1980). In recent years, a great deal of attention has focussed on the role of fibre in the diets of humans and non-ruminants.

This work seeks to elucidate some information on the nutritional significance of fibre in pigs kept under tropical conditions. Two fibre sources, namely 'China leaf meal' (CLM) and brewers dried grain (BDG) are used in this study. CLM is claimed to be lucerne (alfalfa) leaf meal imported from China. Its botanical origin and nutritional value are not well known in Malaysia. Although BDG is produced locally, information on its feeding value are lacking. The study is divided into five parts i.e.

(1) Nutritional composition and bulk characteristics,

(2) Digestibilities and digestible energy,

(3) Effects of levels of CLM and BDG on performance and carcass traits of growing-finishing pigs,

(4) Effects of levels of dietary fibre and energy on performance and carcass traits of pigs,

(5) Effects of levels of dietary fibre and protein on performance and carcass traits of pigs.

CHAPTER II

REVIEW OF LITERATURE

DEFINITIVE ANALYTICAL SYSTEMS FOR EVALUATING FIBROUS FEEDS

Crude fibre determination

The 'Weende' system was proposed in the mid-1800's for proximate analysis of crude protein (CP), crude fibre (CF), ether extract (EE), ash and nitrogen-free extract (NFE). This system was originally based on the concept that CF represented the indigestible portion. For many years there have been varying degrees of dissatisfaction with the 'Weende' method of CF determination which has been used in laboratories all over the world for at least 150 years. In this system, CF is determined by boiling a sample of feed (after fat extraction) successively with 1.25% H_2SO_4 and with 1.25% NaOH, each reagent being employed for exactly 30 minutes. The organic matter surviving this 'digestion' is called CF. This system of analysis fails to isolate all of the fibrous components of plant material (cellulose, hemicellulose and lignin) since up to 85% of hemicellulose, 0-50% of cellulose and 50-90% of the lignin are dissolved in the digestion procedure used (Van Soest and Robertson, 1975). Consequently, the CF figure underestimates the total fibrous materials (cell wall constituents) in plant materials.

The greatest error in the proximate system of analysis is the separation of the carbohydrates into NFE and CF. Since NFE is obtained by difference, it contains the cumulative errors of all the other determinations, the largest has been due to the loss of much lignin and hemicelluloses in the preparation and determination of CF.

The detergent system of Van Soest

Neutral detergent fibre (NDF) is based on the extraction of the feed with hot solution of a neutral detergent consisting of disodium ethylene diamine tetra acetate dihydrate, sodium borate decahydrate, sodium lauryl sulphate, 2-ethoxy ethanol and disodium hydrogen phosphate. Acid detergent fibre (ADF) is based on the extraction with hot, acid-containing detergent consisting of cetyl trimethyl ammonium bromide and sulphuric acid. These methods are described by Goering and Van Soest (1970), which in turn is based on the work of Van Soest (1963 a, b).

NDF is considered by Van Soest to give a good measure of the total cell wall in plant materials. ADF, on the other hand, gives a good measure of the cellulose plus lignin (McConnell and Eastwood, 1974), and can be used for the subsequent determination of these two components.

Waldern (1971) developed a micro-digestion procedure for NDF and ADF analyses. Although the micro method results in greater variation, it has many advantages over the macro method where large number of samples are involved. With this method, the number of samples digested at one time is increased, less reagents are required, and few filtration problems are encountered with feeds that contain a high proportion of starch.

The Fonnesbeck system

The Fonnesbeck system (Fonnesbeck, 1976) is essentially derived from the detergent system. A pepsin digestion is carried out prior to the determination of plant cell wall which is conducted at pH 3.5. This is done to reduce the nitrogen content of the fibre and to eliminate starch interference. As in the detergent system, the analysis can proceed sequentially. However, the sequence does not provide for the fractionation of tannins, cutin and Maillard products. This procedure sacrifices speed for purer fibre fractions.

The Southgate system

In this system (Southgate, 1969 a, b), the dietary fibre is fractionated into lignin, cellulosic polysaccharides and non-cellulosic polysaccharides. The polysaccharides are determined chemically or with the use of gas-liquid chromatography or high pressured liquid chromatography. The dietary fibre is estimated by the summation of the non-cellulosic polysaccharides, cellulosic polysaccharides and lignin fractions. This method requires that the various fractions are progressively removed by selective reagent until only lignin and inorganic ash are left. Between 4 to 5 aliquots are taken for analyses after accurate weighing. Although the analytical methods are precise, it is debatable whether the time and labour required are justified in normal analysis.

Dietary fibre redefined

Van Soest (1978) defined dietary fibre as 'the plant polymeric substances resistant to animal digestive enzymes'. This definition was endorsed by the Fibre Committee sponsored by the Medical Research Committee of the European Economic Community (EEC) and the International Agency for Research on Cancer (IRAC). It contains not only lignin, cellulose and hemicelluloses but also includes pectins, gum, galactans and other soluble materials which are degraded by bacteria and do not contribute to the true indigestible faecal fraction. The insoluble indigested fibre is the principle fraction promoting passage of food residue (Van Soest *et al.*, 1978). Among clinicians, the definition of dietary fibre as 'plant polysaccharides and lignin which are resistant to hydrolysis by the digestive enzymes' has achieved widespread acceptance (Trowell *et al.*, 1976).

The need to have a better system of fibre analysis arises because of the various deficiencies of CF analysis and associated proximate analysis. The A.O.A.C. recommended the discontinuance of NFE in 1940 (Van Soest and Robertson, 1979). The EEC-IRAC Working Committee on Dietary Fibre recommended that CF be abandoned (Theander and James, 1979). The International Organization for standardization (ISO) suggested that CF be replaced by the determination of cellulose. However, the suggestion has been deemed inadequate as cellulose represents only a portion of the total fibre and is a variable portion of it. The two most commonly used systems in present use are the detergent system of Van Soest and the Southgate system.

UTILIZATION OF FIBRE IN SWINE

Fibre fermentation

Early work on the fermentation of fibre by the intestinal flora of the pig, as reviewed by Cranwell (1968), indicated that there was little or no fibre digestion anterior to the large intestine of the pig. However, Clemens *et al.* (1975) reported that large particles of digesta could be retained in the pig's stomach for up to 60 hours. This retention of digesta would allow time for considerable fibre digestion in the stomach and small intestine, provided the conditions of nutrient supply, pH and bacterial population were suitable.

The principle fermentation products of dietary fibre are volatile fatty acids (VFA) and these have been shown to be present in and absorbed from the stomach, small and large intestines of the pig (Barcroft *et al.*, 1944; Elsden *et al.*, 1946; Argenzio and Southworth, 1975). Farrell and Johnson (1972) estimated that the VFA produced in the caecum of a 40 kg pig could supply 2-3% of digestible energy intake. Recent work by Kass *et al.* (1980) showed that the concentration of VFA in the large intestine increased with increasing dietary fibre. Keys and DeBarthe (1974), using pigs fitted with cannulas in the duodenum and terminal ileum, found that up to 20% of the hemicellulose was digested before the duodenum and up to 47% before the terminal ileum. Data reported by Sambrook (1979) indicated that there was some digestion of ADF from the cereal diet in the anterior small intestine of the pig.

Effects of dietary fibre on digestibility and growth

Nordfeldt (1954) reviewed 1560 digestibility experiments with 1698 pigs covering the period from 1900 to 1951. His findings revealed that there was a consistent tendency for digestibility of fibre to improve with increasing weight of the pigs. It is also found that the fibrous portion of feeds influences the digestibility of other constituents, depending on the characteristics of fibre in individual feed. For example, with barley-based diets, a rise in CF of 3% resulted in 1% depression in organic matter digestibility. For diets based on oats, a similar rise in CF level gave a 3% depression in organic matter digestibility, while for diets based on wheat bran, a rise in CF of 3% depressed organic matter digestibility by 10% (Nordfeldt, 1954). Cunningham et al. (1962), using cellulose as a fibre source, found a decrease of approximately 1.1% in crude protein digestibility for each 1% increase in CF. A decrease in crude protein digestibility of 1.6% for each 1% increase in CF was found by Baird et al. (1974), who used citrus pulp as a fibre source.

Reports of fibre digestibility indicate that the degree of fibre utilization in pigs are quite variable. This variation may have resulted from differences in source of fibre, level of fibre in the diet, the character of the non-fibrous portion of the diet, the plane of nutrition and the age of the pigs. Also, if fibrous feeds are fed to pigs in pelletted form, the digestibility of CF is increased (Ngian, 1981).

Early work have demonstrated the inhibitory effect of high levels of dietary fibre on the growth of pigs (Axelsson and Ericksson, 1953; Crampton et al., 1954; Teague and Hanson, 1954). However, more recent studies showed that CF levels in the diet had no effects on rate of gain, efficiency of gain or carcass leanness if the energy density was constant (Cole et al., 1967a; Baird et al., 1970) Bowland et al. (1970) reported that nitrogen retention and energy gain did not change significantly as the CF levels of the diet increased. Baird et al. (1975) further found that it was energy density rather than bulk in the diet that determined feed intake. These latter reports support the suggestion that it is reduced energy intake, and not CF level that is responsible for differences in performance. In other words, unless prevented by bulk or palatability of the diet, the pig tends to eat until it satisfies its energy requirement.

Effects of temperature on fibre utilization

Low-energy and high-fibre diets reduced growth and efficiency of feed conversion in summer but not in winter. Utilization of energy tended to be greater with high-energy diets in summer and high-fibre diets in winter. These were the findings of Seerley (1980) who also reported that average daily gain decreased in summer, but not in winter, with increasing levels of dried alfalfa or Bermuda grass in the diet. Stahly and Cromwell (1981) found that addition of alfalfa meal to the diet depressed the efficiency of feed utilization in pigs maintained in the 22.5°C but not the 10°C environment. Further, alfalfa meal supplementation depressed the efficiency of feed utilization in pigs maintained at 35°C but not at 22.5°C or 10°C. These data suggest that the nutritional value of a feedstuff containing a high fibre level is greater in pigs housed in a cold environment than in those kept in a warm environment.

Use of leaf meals and brewers dried grains as fibrous feeds for swine

Leaf meals, particularly alfalfa meal have been used in swine diets in the West for decades. Besides contributing dietary fibre, alfalfa meal has been used to furnish trace minerals, vitamins, pigments and what has been popularly referred to as 'unindentified growth factors'. Thompson (1958) gave a comprehensive summary of its nutritional content.

Studies in the fifties indicated that when the dietary level of alfalfa meal exceeded 20%, there was a depression in rate and efficiency of gain (Ellis and King, 1952; Forbes and Hamilton, 1952; Becker et al., 1956). A recent study by Kass (1980) also showed that a level of 20% alfalfa meal in the diet did not suppress weight